TRANSCRIPT OF SCIENCE YEAR LECTURE
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SCIENCE AND SOCIETY

I would like to thank the many people who are assembled here tonight, particularly the honoured guests, and especially the Minister and our Chairman for the night, The Duke of York. I want to say one thing at the start about the Royal Society itself. Normally from this room, a portrait of Charles II, the founding patron of the Society in 1660, looks out upon you. The Society was the first organisation that acquired the “Royal” title. These days, of course, there are very many organisations, such as the RSPCA, that also have royal patronage, but at the time that Charles II granted us our Charter, he just thought well, we’ll make this the Royal Society of London for Improving Natural Knowledge. We thus have this curiously quaint, and rather quirky, name, which is not exactly the first thing you’d search for on the Web if you’re looking for the United Kingdom’s National Academy of Sciences – but there it is, and we enjoy it with all its curiosity and its resonance as part of our very, very rich and interesting history.

Over the century that’s just drawn to a close, there have been more advances in our understanding of how the external world works than in all of previous human history. And we’ve used that understanding to make life better, in both the developed and the developing world. It was only as the century drew to a close that we began to recognise and try to grapple with the many adverse, unintended consequences of our well-intentioned actions - climate change and the diminishing biological diversity being two conspicuous examples.

In the century that has just begun, our understanding begins to reach deep inside the external world into the molecular machinery of life itself and this is opening doors, new applications that are going to raise, and are already raising, questions about ethics and safety that make the problems we inherited from the past century really just look like shadows on the wall. We really do live in an epoch that is the best of times and the worst of times. The task for us, and particularly for the generation going through school today, is to try to learn to do a better job of asking what kind of a world we want to make with the possibilities that science offers, subject to the constraints that science clarifies, rather than just letting things happen. That is the problem – not just for science, not just for government, but for all of us, and particularly for younger people.

So, what I'm going to do in the rest of this lecture is to flesh out, in factual terms, what I mean when I say "the best of times" and "the worst of times". And then against that background, I am going to turn to discuss, with my own opinions, how I think we ought to go about managing and handling all this better.

We don't know how our hunter/gatherer ancestors lived 10,000 years ago, before the advent of agriculture, but ecologists can roughly reconstruct the survivorship curve, which on its ***y*** axis tells us the probability of surviving to the given age shown on the ***x*** axis. Once you were born, in hunter/gatherer times, a lot of people got knocked off in the first couple of years and thereafter the survivorship curve looks pretty much like that of the average bird species. Your chance of living through to next year was roughly the same as the chance of living through the previous year, independent of how old you were.

If we now move forward to 50 years ago and look at the curve in the developed world, we see that you had a fair chance, once you were born, of getting your allotted three score years and ten and a bit more. But if you were born in a typical developing world country at that time, it still had much of the character of a bird-like survival curve, although not as bad as in pre-agricultural times.

That was 50 years ago. Best of times? Fifty years ago the average life expectancy at birth was 46 years. Today, it is 64 years. This is a clear measure of life getting better, on average, across the globe. And the average difference in life expectancy at birth between a child born in the developed world and one born in the developing world, has narrowed from the 26-year gap of 50 years ago to a still disgraceful 12 years now.

Best of times? Look at the amount of the average disposable family income that is spent on food and alcoholic drink in a typical developed country. It is about 16% of the total income. It has never been less. Food has never been cheaper, more diverse or more abundant. In the developing world there have been benefits from the fact that over the last 35 years, through the green revolution, we have doubled the world's food production, bringing over 10% more land under cultivation at a time when the world population has grown by about 60%.

There is actually more food per person today worldwide, but the problem is distributing it equitably. That is a deep and intractable problem that has always been with us. But the one thing that is certain is that you could not feed today's population with yesterday's agriculture. All the health benefits from the green revolution that gave us that doubling of food production have been science-based.

Best of times? The average inhabitant of the globe today consumes daily, on average, 14 times the amount of energy that's required just to keep his or her metabolic processes ticking over. As hunter/gatherers, like any other living organism, we consumed enough energy in a day, on average, just to keep ourselves going. Today, we're subsidised on average fourteen-fold by, usually, fossil fuel energy. Of course those subsidies vary hugely between countries. In developed countries, the figures may be more like 40 or 50 times the basic metabolic rate. The developing countries are lower, but on average still pretty large. And in developed countries it drives all manner of things: household appliances; transport; we use it in the office and work place; when we do our shopping. That energy subsidy in daily life has made possible the dismantling of the class structure. Where once there were servants there are now energy-subsidised machines.

At the same time it is the worst of times. One of the unintended consequences of these developments has been population growth. In hunter/gatherer times the human total population was somewhere between 5 and 20 million. Since then it has been slowly and jerkily growing, with episodes of fallback due to plague and surges forward again, so that by about 1830 there were one billion inhabitants of the globe. It then took another 100 years for the population to double to two billion in 1930, and 40 years to double again by the 1970s. Today, the world's population is a little over six billion and we are committed to at least nine billion or so people by the middle of this century. Eighty to 90 million people, much more than the population of the United

Kingdom, are added annually to the global population. The rate of growth is declining, from 2% in the 1970s, to 1.4% or 1.5% today, but because of the young people already born, we are committed to much continuing population growth.

Worst of times? That population growth has implications for tomorrow's food production. In the same way that we could not feed today's population with yesterday's agriculture, we are not going to be able to feed tomorrow's population with today's agriculture. There are many factors in the green revolution that led to a doubling of food production. Among them has been the seven-fold increase in the use of nitrogen fertilisers. And there are signs that the accomplishments of the green revolution are beginning to plateau. Yet if you make forward projections, over the next 20 years or so as the world population grows to an estimated 7.5 to 7.7 billion, the demand globally for cereals will go up 40 to 50%, for meat by 60% or more, for roots and tubers by 40% or more, and in many developing countries those demands will double.

The inevitable consequence is that we need again to double the green revolution over the next 20 or 30 years, and that is going to require, if it is not done in a different way, an increase of two to three times in the use of nitrogen fertilisers, and a doubling in the use of available water.

Here are two ways of summing it up. Human population today sequesters to its own use somewhere between a quarter and one half of all net terrestrial primary productivity. Directly or indirectly, we consume between 25% and 50% of all the green stuff that grew on earth last year. No precedent for that exists. Perhaps even more remarkably, more than half the atoms of nitrogen that were incorporated in green plant material last year, from the sweep of the Arctic Tundra, down through the forests, across the savannahs, into the tropical rain forests, came from fertilizers subsidised by fossil fuels, not from the bio-geochemical processes that build the living biosphere. The impacts on bio-diversity are increasingly documented and we therefore need a doubly green revolution, something that repeats the accomplishment of the green revolution, but in a more sustainable way that works with the grain of nature.

Finally, it is worth stressing that more than 90% of the energy that we consume comes from the burning of fossil fuels, one way or another. Despite increasing consensus about the science underpinning predictions of global climate change, doubts have been expressed recently about the need to mitigate the risks posed by such change. We do not consider such doubts justified. When President Bush last year expressed his doubts about the science, 17 of the world's major academies, led I am pleased to say by the Royal Society, responded remarkably quickly with a statement that the work of the Inter-governmental Panel on Climate Change should be acknowledged as the consensus view of the international scientific community. We recognise the IPCC as the world's most reliable source of information on climate change causes and we endorse its methods of achieving consensus.

And I would like to end the first half of the lecture by turning to some statistics put together by the Worldwide Fund for Nature. What they have tried to do is ask, country by country, how much effective land area we need to produce the food we eat, the clothes we wear, other infrastructures, housing, plants to help maintain and soak up the carbon dioxide in the atmosphere and try and maintain a balanced climate. They counted up all that area, country by country, and looked at it over the last decade, then tried to make an assessment of what is the effective area in total that the globe must have to cater for these activities on a sustainable basis. Although it is difficult to be exact with such a calculation, it does reveal that we exceeded the biocapacity of the globe a couple of decades ago, and that means our overall sustainability is at risk.

So that was a factual introduction to all this. I am now going to share with you some of my opinions about how we should conduct a dialogue and debate about the kind of future we want to build with the increasingly extraordinary opportunities offered to us through our understanding of how the world really works.

It has always been true that science itself depends upon patrons to realise its gain. In an earlier, and in many ways simpler, world, the patrons may have been emperors or kings or sultans or popes. Today, in the democracies of the developed world there are the views of the public. But how do you have an effective discussion with the public in all its various and particular manifestations?

The government, elected representatives of the people, needs to form policies and make crucial choices. But how do you conduct a dialogue when very often the subject of the dialogue depends on extremely complicated and often not fully-understood scientific issues? The science itself offers an opportunity, but it also offers many kinds of constraints that are naturally unpopular. Science puts a limit on utopian wishes: to have everybody well-fed, well-housed, enjoying a standard of living that allows everyone to drive a petrol guzzling four-by-four and yet have continuing population growth. Sometimes those choices are clear enough, sometimes they are very complicated, and sometimes the very experts themselves can only guess.

But before proceeding to say what I think are some of the things we need to be doing, I want to deal with what I think are two major misconceptions that some of my scientific colleagues have about the public, and one major misconception which I think many of the public have about the nature of science. The first of the misconceptions that many scientists have about the public is that the public today distrusts science more than ever before. A cartoon by James Gillray about 200 years ago captures an image that is fully resonant with tabloid cartoons today, after there were riots in the streets over vaccination with cowpox against smallpox. The cartoon shows little cows popping out of people's backsides or arms after the doctors do this bizarre thing: vaccination. Earlier yet, people's distrust of the new manifested itself in the burning of Bruno, or the placing of Galileo under house arrest.

Even hen the railway first came along, people wanted it to be banned because there was a specific worry that, as you went through the long Box tunnel outside Bath, all of the air would be sucked out, and the carriage would emerge at the other end with everybody dead.

At the same time, many of the central issues in these debates touched on things from which we would all have benefited if they had been taken more seriously. The concern about smallpox is a non-trivial technical issue. There were complicated debates about weighing up the small number of people who actually died as a result of the vaccination against the estimate of how many people might die if no one was vaccinated when smallpox arrived.

In fact, if you ask people today, they are probably, on the whole, more enthusiastic about science than people have ever been. The MORI poll that was published by the Office of Science and Technology and the Wellcome Trust in October 2000 found that 84% of people agreed with the statement “scientists and engineers make a valuable contribution to society”. Reassuringly, two-thirds of them also agreed that “in general scientists want to make life better for the average person”. At the same time, with admirable common sense, 41% of people said the pace of modern scientific advance is too fast for effective regulation.

A particularly interesting recent MORI poll, which in light of the age structure in the audience tonight is particularly relevant, placed the various professions in a hierarchy of trustworthiness. Basically, a hierarchy of esteem. Top of this poll tend to be doctors, followed gratifyingly by teachers and then professors and scientists. This was a particularly interesting poll because it broke out separately what 15 to 24 year-olds said from what all ages said. Fifteen to 24 year-olds trusted doctors a little bit more, but not significantly more, than the public at large, and trusted teachers a little bit less, but not really significantly. They trusted television newsreaders roughly the same, but not as much as professors. The public at large actually ranked professors along with television newsreaders, with about 78% saying they trusted them, whereas younger people put them right up at the top with doctors at 88%. All I can say is, I desperately hope these younger people are going to cleave to those beliefs and not become disillusioned as they get older. In short, what has always been true, I think, and is certainly true today, is not that people distrust science, but rather they raise important and interesting questions about it.

The second misapprehension, and a more interesting one among many of my colleagues, is that if only everybody was better educated in science then we wouldn't have any of these controversial debates about genetically modified food or mobile telephones. Nothing could be further, and should be further, from the truth. There are a myriad of polls in different European Union countries, which begin by asking people quite significant, searching questions about how much they know about science. Not the trivia questions, but questions about what is the nature of the scientific method. What do you mean by control group? What do you mean by a statistical confidence interval?

The average country scores on those quizzes show quite a remarkable spread. On a scale of 0 to 100, some of the northern countries score in the 70s - pleasingly the UK tends to score in the 70s, second to Denmark. Then the scores run right down to the 30s in some of the Mediterranean countries. Then you ask the same people: do you think science is unequivocally making life better - on a scale of one to five. The majority in every country say yes, science is making life better. But the strength with which they affirm that proposition, an unequivocal unquestioning embrace of it, is greatest in countries that score lowest on the tests about how much people really know about science.

That's exactly how it should be. I am not saying that therefore we shouldn't aim to educate people in science. That is NOT what I am saying! But what I am saying is the more you really understand about science, the more you understand that there can be Faustian elements to the bargain. There can be unintended consequences from the best-intended actions. Still, that's not to say that we shouldn't aim to have everybody understand it. Of course we should, because we want more people really knowing the hard questions to ask. That's partly what Science Year is all about – getting right in to primary and secondary schools, teaching pupils that.

There is another very recent poll that asked people in the UK, and in the EU generally, where they got their information about science from. And, rather disconcertingly, both in the UK and the EU more generally, only about a quarter of people said from school or university. The major source of information, they said, was from the media. Not surprisingly, in the same poll, only about a third of people felt that they really were well-informed. And amusingly, the people in countries who thought they were better-informed were the same ones who scored lowest on the test about how much they know about science.

Other kinds of studies show that the common sense of the public really can be relied upon. The public don't have general attitudes to something called science. They engage with particular issues that are interesting to them. I'll give you three examples: If you ask people about new medicines, perhaps involving genetic modification, they say they see a risk, they see a clear benefit, they don't see an ethical dimension and they are in favour of them, because they see the benefits that medicine has made in their own and their relatives' and their friends' lives.

If you ask those same people about xenotransplantation, for example putting baboons' hearts into patients, they say they see a real risk, after all HIV got into the population through the bush meat trade. They say they don't see much benefit, which is interesting because people don't see themselves as likely to need a heart transplant. They also say they see an ethical dimension and they are really against it.

Until a few years ago, when you asked people about GM foods, they said they see a risk, but not much of a risk, they don't see much of a benefit, and they don't see much of an ethical dimension. Overall, they don't see the point.

We turn on the other hand to what I think is a quite important misapprehension on the part of the many different publics about the nature of science itself. I would argue that this misapprehension is even held by many scientists about the nature of their subject. It's an understandable but unfortunate misunderstanding - a misunderstanding that assumes science is about facts, science is about certitude. That's understandable, because that's nearly always how we meet science. The form in which we meet science in primary school or secondary school, most of the time in university, and certainly how we meet science questions on 'University Challenge' or 'The Weakest Link' or 'Who Wants to be a Millionaire', is apodictic certitude – a right answer and a wrong answer. It's understandable. How else do you organise a curriculum? How else do you grade a paper? In a quiz show, how else do you say right or wrong? You pick something with a clear answer. Sometimes, of course, it's just a trivial definition of things, and sometimes it's things that are more substantial.

There are scientific advances that have been hardened into virtual certitude. But the problem is that at and beyond the frontiers, that's not what science is like. And many of the problems that we wrestle with are problems at and beyond the frontiers of science where we don't yet know the answers, and sometimes only have good guesses. Sometimes we have a better way of framing the question. But very often we don't have an answer.

The media, who I think in the UK by and large do a super job of reporting science, have a tendency to report things for balance in terms of two sides of an argument – as if science is a kind of football game. The landscape of science is fascinatingly more complex than that once you approach the frontiers. Sometimes there will be two main peaks of opinion representing two different views, and it is like a football game. In other cases, there will be one broad fuzzy consensus, with all sorts of credible or affirmative views obliterating the outer edges of the landscape, but which deserve exploration, and over time it may be that the central consensus collapses and one of those peaks rises. And it will never be, on any issue, that everyone agrees. For instance, there are several thousand PhD holders who literally subscribe to a belief that the world was created in 4004 BC. What happens as science advances, and as things get tested, is that the tentative nature becomes more secure, and you have something that becomes more rational and becomes more routine, but at the frontier it often remains a total shambles. It is at that point that it becomes very pernicious to try to represent both sides equally, when one side is 99% of informed opinion but which recognises that it may yet be wrong, and the remaining 1% is an unrepresentative sample from several different alternative views.

This has relevance not just to the teaching of science, but also to the handling of science in government. Almost all of the time, science in government – technical issues of various kinds – can be handled very, very reliably and nobody worries, nobody needs to raise questions because it relates to that area of science that's well-established. And for that, you can rely on the journey men and women of science. They serve you better than a Nobel Laureate because they won't get bored with it and they will do the business.

But when you go beyond the forefront of our knowledge, you really do have to look at the special people who inhabit that frontier, who are not altogether the same as the larger number of people who do extraordinarily important and useful work in laying down 'railway tracks' in the areas behind the frontier. There is an analogy I am fond of. In the Dolomites, there are things called *Via Ferrata,* where pioneers have climbed the bare rock-face to put up ladders and fixed cables, so that people who couldn't scale the climber's wall at your local gym can clip themselves on with perfect safety and go along the cable, enjoying the misleading thrill that they are being like the pioneers.

There is a dimension of that to science in that there are problems that you can handle with the *Via Ferrata*, with ladders and fixed ropes that earlier generations of pioneers have put up and where opinion has coalesced around. But our real problems are at and beyond the frontiers, and those are the problems that we are having to grapple with. And there you need the people who can climb the bare rock. They are not always easy to find.

What are some of these problems I keep referring to? Well for instance:

- How should we make use of our increasing understanding of embryonic stem cells? Should we indeed make use of it? Should we extend research on early human embryos, which we legalised in this country 10 years ago to deliver fertility benefits. Such research is still illegal in some countries, but we have warmly embraced it and created much human happiness.

- What further tests should we carry out on genetically modified crops? What is their role in future of agriculture? What future use should we put them to? Will they help us realise the age-old agricultural dream of growing crops that nothing eats but us - not shared with weeds (plants in the wrong place), and not shared with pests (insects with the wrong appetite). How should we proceed because if our only focus is a more efficient agriculture then we will see an ever more silent spring?

- There are still many important questions to answer about HIV. Where did it come from? How should we handle AIDS? What drugs should we supply, and at what cost?

- More questions about BSE. When the early questions first arose, we made what at the time was overwhelmingly the best guess – that this new scrapie-like disease in cattle would not infect humans. That was the best guess, but instead of saying “this is our best guess” we let it slide into a certainty, with a

Minister saying it was “perfectly safe and here’s me feeding my daughter a hamburger to prove it.”

- Xenotransplantation, with many ethical and safety questions.

- Genetic databases. The House of Lords has debated this issue and raised fascinating questions about the protection of personal information and the role of insurance companies. At the same time, there are issues like how we use these databases to learn about the variety of human genomics and how we deliver profound medical benefits that can only come from access to an appropriately anonymised database.

- How do we handle the safety worries people have about mobile telephones?

The catalogue is virtually endless, but it’s nothing but a catalogue of things that are going to unfold as we begin to ask harder and sharper questions about, for example, who owns the human genome sequence data. What uses should we put that knowledge to? And ultimately, born of the already surprising discovery that we share a far larger proportion of our genes with other animals and plants, how do we see ourselves as part of life on earth?

How should we handle all these things? A large part of the answer, of course, lies in the way that we teach science in schools. We have to learn to teach science as a way of knowing. To teach science as a way of asking questions about the world. I think we are increasingly doing a good job with that, but it’s tricky because at the same time you do want to measure the standards of success. It's not enough to just get out there and say we're going to give people a toolkit. You've got to test to see whether they can use the tools, and the tests have to have right and wrong answers. It's a tricky road we have to learn to tread.

Many of my colleagues think that one of the measures of success in teaching science well is that it seems to be endless fun, fun, fun all the time. But nothing is fun, fun, fun all the time. David Beckham's life is not just fun, fun, fun and fame. He spends hours practising free kicks. Boring but necessary. Science at school is a mixture of this, but above all it has to be animated by the guiding notion that is at the heart and soul of science - that science is a way of understanding the world. It's not an easy trick to master, but today's world, in many clear and quantitative senses, is a better place to be by virtue of the understanding achieved by a scientific approach.